Building Information Modelling design ecologies - a new model?

BUILDING INFORMATION MODELLING DESIGN ECOLOGIES – A NEW MODEL?

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This paper considers the barriers to BIM adoption and demonstrates they are symptoms of existing problems in the Architecture, Engineering, Construction, and Operations (AECO) industry. When current external pressures are considered, a varied and complex set of problems emerge that require a significant paradigm change if they are to be resolved sustainably. It is argued that Building Information Modelling (BIM) does not represent a paradigm change on its own and the concept of the design ecology is presented as a framework within which BIM can act as a catalyst for change. Specific affordances of this model are presented in terms of responding to the challenges presented in the Low Carbon Construction report (Innovation and Growth Team, 2010) and to the general characteristics of the original problems identified. Examples are presented to demonstrate that this is already emerging in practice and some suggested areas of further investigation are suggested.

Keywords: Building Information Modelling, collaboration, design ecology, design process, low carbon construction, paradigm change, sustainability.

1. INTRODUCTION

In Autumn 2010, the Innovation and Growth Team of the Government Construction Advisory Committee published its final report, *Low Carbon Construction* (Innovation and Growth Team, 2010). In this report, the transition of the AECO industry to a low carbon economy is questioned and the potential for Building Information Modelling (BIM) is specifically noted:

"Its particular significance in the context of carbon is not just that the importance of integration to a new, more reliable and less costly proposition that the industry needs to bring to the carbon reduction programme, but also as an instrument of systems engineering, with the potential to model different scenarios."

This single quotation is aspirational in terms of the scale and complexity of the goals it seeks to address. Responding to low carbon design and construction will be difficult enough but a systems engineering approach will require a significant paradigm shift in the way the AECO industry operates.

The industry faces an immediate challenge. BIM offers the opportunity to change the way it works but it also offers the chance to simply continue existing processes more efficiently. The challenge then is to whether the industry will continue with existing practices or engage in real change to meet the complex challenges we face today.

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2. PROBLEMS

2.1 Old problems

BIM is potentially a new and different way of designing, constructing and operating buildings and the built environment. As such, it arguably joins a list of ‘ideas’ that have attempted to improve the Architecture, Engineering, Construction and Operations (AECO) industry over the years. The *Low Carbon Construction* report referred to in the introduction acknowledges the need to still work on problems previously identified, citing both Egan and Latham. The reports *Rethinking Construction* (Egan, 1998) and *Constructing the Team* (Latham, 1994) both identify critical and wide-ranging issues and proposed a range of institutional and process changes. Latham identifies specifically the fact that “Previous reports on the construction industry have either been implemented incompletely, or the problems have persisted.” (Latham, 1994, p vii).

Yet significant change has yet to occur beyond individual exemplar projects and these reports have not resulted in transformation to where *good* practice might be said to have become *normal* practice. Change, it seems, is something that the AECO industry finds particularly difficult and this is not because the problems cannot be solved – they can. For example, trust and cooperation in project teams (Kadefors, 2004) or genuine partnering approaches (Thompson & Sanders, 1998). But there seems to be a need to retain existing paradigms of practice as if there were no alternatives.

2.2 New problems

The adoption of Building Information Modelling (BIM) software applications in the AECO industry accelerated in 2011 yet uptake still remains slow in certain disciplines (NBS, 2012). More importantly, the use of BIM, beyond that of an efficient software solution, to genuinely foster collaborative BIM Level 2 maturity processes (as defined in (BIM Working Party, 2011)), has yet to be achieved in the commercial environment (Rawlinson, 2012). This is all despite the growing body of experience and research demonstrating the benefits of BIM as a process, for example, Malleson in (NBS, 2012), International Alliance for Interoperability (2010), or Chevin & Crotty (2012).

As the awareness spreads, so too do the barriers and objections to its mainstream adoption. As noted by the UK Government’s BIM Working Party, *“Whenever change is identified barriers are cited…”* (BIM Working Party, 2011), and this could be seen as a truism for any institution facing change. But the shear range of barriers to BIM adoption is interesting and a few brief examples are presented below.

Fragmented processes. These occur at all levels of practice, from separating specialist designers right through to fragmented procurement. At each stage of the process there is a limit to what can be achieved and it is rare to find a project that doesn’t stop and start in some way and this is now a specific problem with BIM processes, where the most effective methods depend on continuity, not disjunction.

‘Lonely’ and ‘Selfish’ BIM. The AECO industry is generally poor at collaborating and many of the institutions we rely on have no interest in improving this. Indeed, many of these institutions rely on the fact that collaboration happens rarely. Aran Verling in discussion with David Philp observes that *“We’re sitting in a fragmented industry that makes money from fragmentation, that struggles to see the value in integration”* (Chevin & Crotty, 2012). This view was observed by both Latham and Egan long before BIM became a recognisable term. But BIM processes require the rapid and open sharing of information between stakeholders.

Education and Training. With a rapidly evolving set of technologies, our educational institutions struggle to keep up with developments in practice. BIM very much requires both theory and practice to be embodied – the 'idea' of BIM and how it works both require attention. Technical learning and information memorisation are effectively useless pedagogies and different teaching and training models are required (Stothart & Wood, 2011).

Legal issues. Questions around ownership, responsibility and liability are the most commonly asked by practitioners. The essential problem here is that legal institutions are reactive, not proactive – since there are no precedents for BIM processes, there is no legal framework. Once again, the speed and range of change are simply too much for legal institutions to deal with.

These are simply a few examples of the emerging barriers to collaborative Level 2 BIM Maturity and these will only grow as the industry adjusts to Level 3 BIM Maturity, where genuine collaboration will be required. The point being made here is that through the implementation and use of BIM as a process quite a few barriers are being raised. But it is argued that the vast majority of these are issues that have been identified already – the BIM process is simply highlighting existing problems.

2.3 Context Pressures

At the same time, the industry faces incredible challenges from the context in which it operates. The current economic crises have yet to show much sign of abating and pressures on infrastructures, resources and energy are now starting to really be felt. Issues of resource scarcity coupled with on-going increases in global population and decreases in waste sinks raise critical questions concerning the nature of the relationship between humans and their environment over time.

Such questions highlight the need for a different type of thinking that reflects the interdependence of complex, natural and artificial systems; such thinking needs to recognise true ecological limits and work intelligently within them. This is in stark contrast to current economic models that encourage linear resource flow and perpetual growth. Within this frame of activity individual and organisations have a long 'horizon of influence' where decisions and actions taken today have uncertain and undeterminable effects in other systems over time.

Sustainability cannot be viewed as an 'add-on' to design and construction processes; as just another constraint. This type of approach limits outcomes to efficiency gains at best and reduces the potential for interconnectivity between the sector and its external actors. Bolting on sustainability issues to current strategy and practice results in actions that reflect the norms of long-established practices by the sector and its institutions. This type of thinking will limit efforts to achieve the necessary gains in resource productivity (say 90 to 95 per cent) required by mid-century (Schmidt-Bleek, 2007) to counter population growth and linear models of resource throughput.

To paraphrase John Maynard Keynes (1936), *'The difficulty lies not in the new ideas, but in escaping from the old ones…'*. We need different starting points, multiple contexts and interesting questions that challenge the social norms and explore our collective 'blindness' to activities and outcomes that are familiar but unsustainable.

John Ehrenfeld (2006) discusses the requirement to move away from 'quick fixes' to complex problems that result in subsequent negative side effects, to a position of finding more fundamental solutions to the initial, complex problem. For example, growth in material use is responded to by a quick fix of integrating greater emphasis on resource efficiency. However material use growth continues resulting in eco-system collapse. A fundamental solution to material use growth is implementing a restructuring of industrial processes such as a greater emphasis on closed loop cycles rather than linear throughput of materials. These fundamental solutions challenge practice at its core and are therefore much harder to implement in practice.

In terms of professional training, new skills also need to evolve and for these to develop some of the existing ideas should be 'let go' to allow room for new thinking and practice to emerge. As systems analyst, Donella Meadows discussed in her report to the Balatan Group (1998), - if we are to manage our way to sustainability, we must make the change from valuing what we measure to measuring what we value. Perhaps the reasons for this is that often things that are of value are also the things that are less easily quantifiable and measureable and require greater time (and by default, cost) to fully comprehend.

Meadows also proposed nine key intervention points for interrupting a system (1997). The least effective of these, in terms of opportunities to challenge and change a system, is a focus on numbers (financial, standards, fiscal) and materials (stocks and flows); these are the current preoccupation of our management and decision-making systems. In contrast, the most impactful intervention points address the goals and rules of the system and opportunities for self-organisation within it – these are things today that we spend very little time and energy on.

Therefore the limits to sustainable change in AECO industries are bounded by the limits of perspective on stakeholders' practices. In creating sustainability, the challenge for the construction sector is to deeply understand and integrate new forms of resilient systems, cultures and operations. New types of products, structures, services, systems and operations that help build sustainability will need to be imagined. Architects, designers and engineers have the capacity to redraw the story for their sectors and for society; to generate viable and more sustainable outcomes and develop adaptive capacity and creative resilience as cornerstones for sustainability.

2.4 "The perfect Storm"

What we carry forward from the previous sections is the fact that there is a wide range of diverse and complex problems facing the industry but four observations emerge.

Attitudes and Paradigms. First, each one turns out to be a difficulty of changing attitudes and paradigms – whether this is the paradigm of habitual working practice when working with others or the paradigm of an institution. Philp refers to this as the challenge of appealing to 'hearts and minds' (Chevin & Crotty (2012)) in the AECO industry, a necessary activity to convince and encourage positive change.

Scales. Second, they occur at a range of 'scales', from the individual right up to national and global domains. The context within which the industry operates can no longer be ignored and current pressures are already effecting change. Moreover, the domains of these problems are also extremely varied – from social issues to resources and energy. One of the challenges of working in the AECO industry is that it impacts on almost all aspects of society, culture and our physical environment.

Complex Problems. Third, they all represent difficult problems. In fact, they could easily be considered tangled or wicked problems where the only solution to these problems "…are not true-or-false, but good-or-bad." (Rittel & Webber, 1973).

Dynamic Problems. Fourth, these changes are happening very quickly and institutions are not equipped to deal with such rapid change. The acceleration of change is a significant factor and it requires institutions to not only respond quickly to change, but to even start responding dynamically or proactively. In effect, making change and adaption parts of normal working practice.

Simply put, we face a range of pressures and problems across all sections of the industry and beyond – what Philp refers to as the 'perfect storm' (NBS, 2012). This represents an unprecedented set of problems and the deeply ingrained working practices, preconceptions and approaches that currently exist are not able to address these issues effectively. A significant paradigm shift is required.

3. PARADIGM CHANGE AND DESIGN ECOLOGIES

3.1 BIM as a paradigm shift?

Several authors have noted the potential paradigm shift that BIM represents: Shelden (2009), Brady (quoted in (Sinclair, 2012)), or Bernstein (quoted in (Stothart & Wood, 2011)) and this is now questioned when the previous sections are considered.

Firstly, BIM highlights *existing* problems in the processes the AECO industry adopts but it cannot solve these problems in itself. BIM processes are more effective and efficient when paradigm-changing practices are adopted but the tools of BIM can also be used with existing paradigms. BIM software can undertake certain tasks very efficiently indeed and it is entirely possible that these immediate and short-term benefits will be used to do 'business as usual', ignoring any longer-term value that may be achieved. In other words, BIM can also be used to reinforce existing, failed paradigms.

Secondly, paradigm shift requires a change in attitude and approach and this can only come from the stakeholders involved in the paradigm. As Khun suggests in *The structure of scientific revolutions*, paradigm change is not a simple mechanism and it certainly does not operate rationally or predictably (Khun, 1962). A paradigm requires a community of consensus to exist in the first place and, by extension, a change or shift in paradigm requires the community to 'agree' to that change. In other words, BIM cannot change a paradigm – only people can.

If BIM on its own does not represent a paradigm shift, then we need to expand our thinking.

3.2 A Design ecology framework

Interconnectivity across systems of systems (the ecology of a system) presents opportunities for interventions addressing the goals and rules of a system alongside the more traditional focus on quantifiable assets, outputs and gains (Meadows, 1997). Ehrenfeld (2008) suggests the need for industrial and societal systems to shift from viewing sustainability as an optional, 'add on' attribute - he terms this view 'reducing unsustainability'. From this perspective activities are limited in their scope and can include managing resource efficiencies or responding to fiscal or regulatory drivers. Ehrenfeld suggests an alternative to these strategies, viewing sustainability as a core driver for new values and goals and terms this perspective 'creating sustainability'.

This perspective challenges the rationale and values of what we currently do to evolve a different understanding of human-ecology relationships that require establishing different types of system goals and rules (a shift in paradigm).

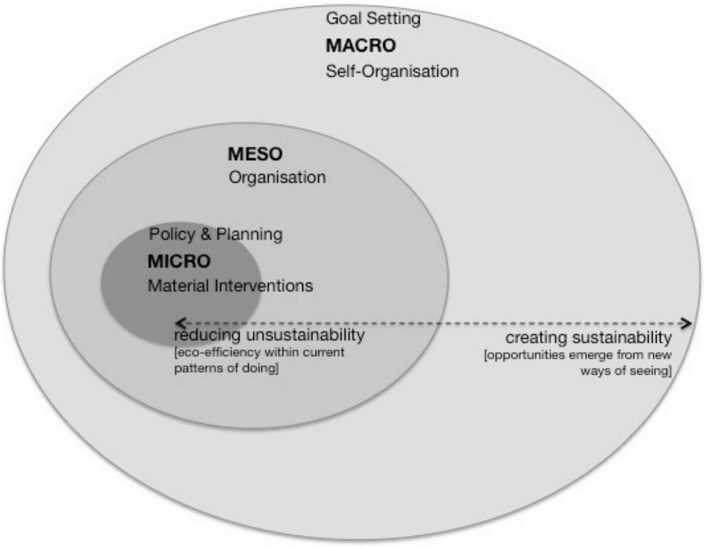

Fig. 1 Shifting the emphasis of approaches to sustainability

Drawing on Ehrenfeld's creating sustainability approach, the design ecology addresses the system relationships within and between design values and activities and shifts away from focusing on single issues in isolation. It is a context-framing concept that identifies relational boundaries, effects and trade-offs. In creating a sustainability approach these boundaries are broad and thus the contexts of design strategies and practice inevitably encompass complex interactions at multi-scales and across timescales. This temporal element reflects long-standing concepts associated with sustainability such as the precautionary principle and inter-generational equity.

The design ecology has a holistic approach to both the object designed and the process of design in that it has an aim only – objectives and goals may serve the process, but they can also change in response to complex elements, some of which have been suggested already. Indeed it could be argued that this is one of the key identifiers of a design ecology - adaption through collective change – and it is this adaption that is of interest here. It is argued that the significant challenges facing the AECO industries can only be solved by significant adaption and the type of thinking and approach required by a design ecology.

4. THE BIM DESIGN ECOLOGY

It may already be seen that the opportunities of BIM and the affordances of the design ecology fit together quite well but the argument being made here is about how these two relate to one another – that BIM is acting as a catalyst for change and that this allows some of the key features that a design ecology requires to form. It is further argued that what might be termed BIM design ecologies are already emerging as a response to BIM Level 2 BIM maturity and it is entirely possible that this will develop further as a result of moving towards Level 3 maturity. To demonstrate this, the four problem themes identified in section 2 are now considered in greater detail.

4.1 Changing attitudes and paradigms.

BIM requires collaboration if it is to work effectively (Morell quoted in (Stothart & Wood, 2011)). In a BIM environment, coordination is very easily achieved but when this coordination is extended to cooperation and beyond, the BIM environment becomes the focus of an even richer set of design behaviours (Grilo & Jardim-

Goncalves, 2010). Individual stakeholders are able to involve themselves in the domains of others and this allows the crossover of methods, ideas and solutions. The effect of community also has a significant impact on learning and knowledge sharing as demonstrated in research (Hakansson, Havila, & Pedersen, 1999) and practice.

It is therefore essential to understand differences in levels of interaction between stakeholders in the AECO industry. Pollard (2005) describes the essential differences between Coordination, Cooperation and Collaboration. In a similar but more substantive work, Thompson & Sanders (1998) suggests Competition, Cooperation, Collaboration and Coalescence as differing levels of interaction between stakeholders. In both of these examples the common principle is that increased alignment of activity, communication and objectives leads to benefits. Moreover, the reduction of alignment leads to significant loss of benefit to individuals and projects – a central observation made by Egan and Latham.

In addition, we have already seen that the connection of extended stakeholders in the wider context is required to solve complex problems. Failing to engage with the wider community within which the AECO industry operates has led to significant problems in the past – again, a point made clear by Egan and Latham.

It is proposed here that a BIM design ecology will arise naturally from a genuinely collaborative BIM process, simply because of the need for, and emergence of, community. By engaging in this ecology, the existing paradigms that discourage collaboration are less likely to be tolerated since they can actually hinder the process. This automatically generates a paradigm shift simply because the community that emerges will create it.

To provide a brief example of this from commercial practice, it is worth considering the value placed on an extended design community and process by John Lewis Partnership and Waitrose Development Construction Manager, Brian Arscott (presentation to RICS BIM Conference (RICS, 2012)). In this example, the value of a continuous design community arose through the development of a continuous BIM for each development project. This in turn led to the establishment of a new paradigm of defining, procuring, constructing and managing the process of creating and managing the built environment.

It is clear that it is both possible and beneficial to engage in paradigm change but more needs to be done to widen the ecology even further. More research into the communities established in this new paradigm is required in order to test whether they are significantly different or whether further paradigm shift is yet required.

4.2 Scales of problems

The BIM is, in many ways, independent of the information being placed in it. This allows the BIM to extend its scope beyond that of traditional domains. As a simple example, incorporating construction sequencing into the BIM environment can allow design and construction to align effectively, a process that is known to improve safety on sites and reduce waste (Jongeling & Olofsson, 2007). This is only one example of the extension of the BIM environment and it cannot be stressed enough that any other stakeholder elements that can be quantified *or qualified* can be incorporated. This means that any scale of design or problem can be simulated and explored.

BIM, as a representation of systems of systems, offers great potential to facilitate a necessary shift in AECO sector priorities to encourage new types of dialogue along the entire conceptualisation, design, construction and delivery lifecycle. Innovation that shifts perspectives, both strategically and practically, can only come about through effective, inter-disciplinary and inter-sector collaboration, drawing out new types of visions and outcomes.

Once again, this is an aspect of the design ecology that is required for its success – the BIM process allows this to occur (in fact it may inevitably emerge) and the design ecology requires it since it cannot fail to respond to the wider issues and context, irrespective of the scale. In effect, the BIM design ecology will cascade up and down scales naturally, embracing early stage stakeholders, and ultimately forming a circular process of designing, constructing and managing the built environment.

This process of inter-disciplinary working is already starting to emerge through the use of BIM processes and the Government strategy to procure all public projects at Level 2 BIM maturity (HM Government, 2011) will hopefully encourage this in the Client domain – both at the design and management stages. The simple argument being made here is that this extension of the 'normal' domain of the AECO industry will begin to address wider and more valuable scales of problems rather than focus on limited and immediate ones.

We have yet to scratch the surface of what might be possible by expanding a BIM design ecology longitudinally and ideas such as BIM 360 or the modelling of the London Urban Heat island (Kolokotroni, Davies, Croxford, Bhuiyan, & Mavrogianni, 2010) across multiple aspects of the built environment are just a couple of interesting examples of this concept emerging into practice.

Once again, the benefits of adopting such attitudes and processes are clear but more needs to be done to encourage use – especially in terms of realising the real and necessary value of dealing with longer-term value rather than shorter-term gain.

4.3 Difficult problems

Shared information provides a significant conceptual and organisational focus and internal framework and this works at a variety of scales. At a simple level, BIM can be used to improve communication (Marshall-Ponting & Aouad, 2005). Anyone who has experienced a BIM workflow will understand this immediately, but there are potentially more significant factors at work.

Jornet & Jahreie (2011) demonstrate clearly that a single shared information environment immediately coordinates the stakeholders' communication and also allows the potential for this to develop into collaboration, acting as a catalyst for the development of cross-discipline communication and working. Linderoth (2010) demonstrates how BIM can operate in reflection of the networks created during the construction stage, leading to deeper levels of communication and interaction. Beyond this shared information resource exists a landscape of opportunities for collaboration through the development of cross-discipline communication and working. These more strategic aspects of BIM provide new spaces to question different priorities and directions for construction processes and outcomes.

Once again, it is argued that BIM offers the opportunity for conceptualisation of complex problems and a design ecology requires them to be solved. Indeed, it could be argued that the BIM design ecology does not merely allow difficult problems to be addressed, it requires them from the very start. At the early stages of the design process, it is simply not possible to have defined all aspects of the problem or even the problem domain. But it is actually possible to incorporate uncertainty and complexity into the design process itself – in fact, it is better to acknowledge the risks and unknown elements than to ignore them and resolve them during construction. Even 'simple' difficult problems, such as optimising a solution for a series of stakeholders, is made that much easier by engaging in a single environment. Having this environment as the focal point for discussion and communication allows meaningful exchanges to occur and validation becomes more effective.

There are many examples of this taking place in practice already – BIM in healthcare has proven itself to be an effective medium for the resolution of complex stakeholder validation and beyond (Lega, 2010). Complex problems are only difficult when a solution is sought – when it is recognised that no single solution exists, then all stakeholders will engage to find the 'best' solution. This is the simple lesson from healthcare design and there is still much to learn in terms of how this process can be made more efficient and effective.

As with the other problems themes presented, further research will be required. In fact, as an aside, it is argued that 'research in practice' should be used to propose, test and evaluate incomplete processes that address complex and difficult problem domains. Practice needs to get much better at research; and research needs to understand that practice is moving ahead at pace.

4.4 Accelerating change

For the existing, traditional paradigm, change is anathema and substantial mechanisms and institutions have grown up to deal with change – in effect becoming sub-industries in their own right. As identified in 2.2, many of the institutions that support the AECO industry are extremely difficult to change in the sense that they are reactive rather proactive entities. But the stakeholders that engage in a BIM process have actively engaged with a constantly evolving set of technologies that underpin the BIM. In fact, it could be argued that those stakeholders that have responded to change have not only embraced it but have actively embodied the *idea* of change.

By this it is meant that change has become part of the process itself and no longer seen as damaging or counter-productive. This might simply be because the communities of practice that have evolved represent the Innovators or Early Adopters identified by Rogers (2003) of innovation uptake. It is argued that change itself is a necessary characteristic required to deal with the complexities of current problems. A BIM process offers the opportunity for change and this can be seen as an extension of the potential that BIM offers to deal with complex problems – simulation of possibility is possible in a BIM process.

A design ecology is necessarily responsive to change – indeed, it could be argued that change is the natural state of any ecology. By this it is meant that processes such as adaption, evolution and reconfiguration to a wide variety of elements are the means by which the ecology forms and sustains itself. The original idea behind competition in the market was not one of economic measurement – it was one of ensuring that better models survived whilst less effective ones were removed. The design ecology allows genuine competition to occur but this competition is measured across a wider range of metrics, avoiding the problem of measurement against a limited (or single) set of criteria.

The BIM process offers the potential for *dynamic* change to be incorporated in the design process and the design ecology depends on it to offer the most effective solution across a range of criteria. But this is an extremely complex and challenging proposition for the AECO industry (Eriksson, 2008).

There are a few interesting projects emerging that acknowledge that complex problems cannot solved and that adaptive or incomplete buildings might help to 'find' better solutions (Paul Fletcher, presentation at RICS BIM Conference (RICS, 2012)). Another (surprising) example might be the response of some in the legal and financial institutions where there is a growing recognition of the need for simplifying legal vehicles or providing dynamic insurance products. These are very much at the cutting edge of what might be possible but if institutions such as these can change then surely there is yet hope for the AECO industry.

The idea of change as part of the process itself should be considered further and monitored to understand whether sustainable change can form part of the culture (or paradigm) of the AECO industry. How this is incorporated into processes of design might represent a key challenge and opportunity.

5. CONCLUSIONS

It is no longer enough to design a building as an object in isolation and it never really has been. In fact, it is quite remarkable that at the end of a construction project the built object is portrayed as a complete solution – where the design team moves on to the next project and little testing or verification of purpose is attempted (and even less adaption or change takes place).

In order to start dealing with the range, complexity and diversity of problems identified in the Low Carbon Construction Report referred to at the start, a significant shift in attitude and paradigm is required. In this context what does sustainability mean for the AECO sector and how can BIM effectively stimulate different types of thinking and responses to these complex and long-term issues?

Whilst it has been argued that BIM does not, in itself, represent a paradigm change, it clearly highlights existing problems and is certainly a potential challenge to how the AECO industry operates – provided that the industry also engages in attitude change. Simply using BIM to do 'business as usual' will not solve current problems. A deeper and more fundamental shift in attitude is required to genuinely engage with the complex problems of sustainability in a changing world.

BIM can certainly act as a significant catalyst for this shift but it also requires the community that uses it to change. The scale, complexity and changing nature of these problems are hard to deal with but with a suitable conceptual framework and a catalyst, the BIM design ecology can offer a platform to start the process.

But more needs to be done to enable and encourage the success of the *process* of BIM and the *understanding* of design ecologies – not simply the output from these models. This will be all the more important as the industry moves towards Level 3 BIM maturity and the hardest part will be to move away from short-term 'add-on' fixes to seek long-term sustainable solutions – to 'create sustainability'.

Too often the industry has failed to respond to past problems – it is now becoming clear that these failures themselves are unsustainable. We have, perhaps, reached 'peak failure' and require a new model of thinking and approach.

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